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ABSTRACT

The objective of this environmental studies unit is to establish a water quality monitoring project for high school students in Alberta while simultaneously providing a unit which meets the objectives of the Biology 20 program (and which may also be used in Biology 10 and 30). Through this project, students assist in the collection, identification, and tabulation of the invertebrate fauna of selected Alberta rivers. The project not only develops an awareness and critical understanding of the environment and current social problems (such as pollution), while contributing to the development of vocational knowledge and skills, but also represents an additional attempt by Alberta Environment to accumulate scientifically reliable information to determine areas of concern and whether remedial action is necessary. This student manual includes information on: (1) field materials and methods (including collecting techniques); (2) laboratory methods, materials, and data analysis techniques; and (3) writing a laboratory report. (JN)

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WATER QUALITY MONITORING EDUCATION PROGRAM

STUDENT MANUAL

SE045161

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Alberta
ENVIRONMENT
Pollution Control Division
Water Quality Control Branch

STUDENT MANUAL

WATER QUALITY MONITORING

AN

ENVIRONMENTAL STUDIES UNIT

FOR

BIOLOGY 20/30

ALBERTA
ENVIRONMENT

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INTRODUCTION

Pollution is not a new word nor a modern phenomenon. From the time man stopped being a hunter-gatherer and became a farmer, there has been man-made pollution. These problems were first documented by Aristotle who mentions the white colour produced by foul mud and the small red threads growing out of it -- sewage fungus and sludge worms.

Imperial Rome was well acquainted with the problem of pollution generated by large numbers of people living in a small area and developed highly sophisticated sanitary and sewer systems and government agencies to administer them. This level of organization was not duplicated until the early twentieth century.

After the decline of the Roman Empire, the management of waste and pollution was essentially ignored by western civilization and major societal disasters may be attributed in part to pollution. The best example was the Black Death or Plague which in the fourteenth century killed one in three people in western Europe.

Historically, pollution has been a result of land modification, soil erosion and the poor disposal of animal and human wastes, although the impact of industrial activity has also been documented. The best definition of pollution is the contamination or destruction of the purity of the world about us.

There is a little doubt that pollution issues today have much graver significance. The two main causes are: (1) the population explosion with heightened awareness of sanitation, and 2) the rapidly escalating technology of modern society; the rapid development of industries with waste products of new chemicals and drugs, and the nuclear age.

Today most national, local and municipal governments in Europe and North America as well as the developing countries have agencies responsible for monitoring and regulating pollution levels in water, air and land. The business of obtaining data is massive and it is important to realize that the general public has a vested interest in the quality of the environment and can assist in this area.

In Alberta as elsewhere rivers are the recipients of numerous industrial and municipal effluents. One of the roles of Alberta Environment is to monitor the effects of these discharges on the water quality of receiving streams. A number of sampling sites have been established from which water samples are analyzed for their physical and chemical properties at regular intervals. This together with a number of strategically located automatic water quality monitors forms a chemical network for water quality data collection. To complement this network, a biological water quality monitoring program was established. However, insufficient manpower did not allow this to be an ongoing programme nor was the entire province covered.

In 1982 and 1983 several schools in Edmonton, Calgary, Red Deer and Grand Centre began a pilot study of the Water Quality Monitoring

Program. The program included the collection and identification of benthic invertebrates from selected sites on the North Saskatchewan, Bow, Red Deer and Beaver rivers by grade eleven and twelve biology students. The data collected was used to determine the effect particular effluent sources such as storm sewer discharge, sewage effluent and wastewater from industrial plants had on aquatic invertebrate life. Such a study helped to determine changes in water quality along the course of the river.

With the assistance of high school students it is hoped that a continuous and comprehensive network of biological monitoring stations can be established. Each participating school can be responsible for one or two stations. The data collected will be stored in computer files by the Department of Environment and will be available as a continuous record of the health of Alberta rivers.

This student manual has been designed for the implementation of a macrobenthic fauna survey to determine water quality at the high school level. It includes such information as equipment required, sampling procedures, laboratory techniques and analysis of data. The unit of study itself is designed to provide the student with an opportunity to experience the role of the freshwater biologist in collecting field data -- interpreting information and suggesting positive action for maintaining the quality of our valuable water resource.

Through this project, students can assist in the collection, identification and tabulation of the invertebrate fauna of selected Alberta rivers. The resulting information can then be incorporated into a laboratory research paper to meet the requirements of a pollution or ecology project in the biology program. A valuable contribution by students will be the statistics gathered regarding types and numbers of macrobenthic invertebrates which will provide further data for Alberta Environment's water quality program.

This program not only develops an awareness and critical understanding of the environment and current social problems (such as pollution), while contributing to the development of vocational knowledge and skills, but it also represents an additional attempt by Alberta Environment to accumulate scientifically reliable information to determine areas of concern and whether remedial action is necessary.

MATERIALS AND METHODS

1. FIELD

A. Materials:

Neil cylinder
small straight shovel (approx. one metre long)
2 nets (mesh size 210 um)
brush
bucket
plastic beaker (400 ml)
plastic funnel (approx. 15 cm in diameter) covered with netting (mesh size 210 um or smaller)
forceps
thermometer
metre stick
labels
pencils
clipboard
vials or small glass bottles (containing 70% ethanol)
hip waders
rubber boots

B. Methods

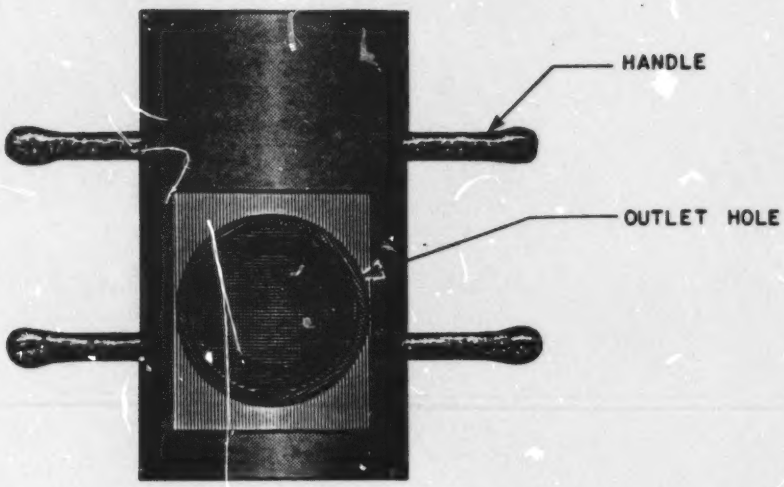
Benthic samples are collected using a modified Neil cylinder. The dimensions of the cylinder are 69 cm high and 34.7 cm wide and the area sampled equals 1 square foot or 0.09 square metres. Along the sides of the cylinder are a circular inlet and outlet hole, 20 cm in diameter. A net (mesh size 210 um) is affixed to the outlet hole in which the sample is collected (Fig 1, page 4.).

The sampling procedure is as follows: The operator should select a location 10 cm-50 cm in depth in which the bottom rocks are all of fairly uniform size. Areas with large rocks should be avoided since they make sampling more difficult. The area to be sampled should have a fairly strong current so that organisms are easily swept into the collecting net. Avoid regions with very strong currents since the cylinder may be difficult to control in such waters. Once a location has been selected, approach the site from downstream and do not disturb gravel, which will dislodge organisms in the immediate sampling area. The location in which the cylinder is placed must be undisturbed otherwise the types and numbers of organisms caught will be affected through sampling error.

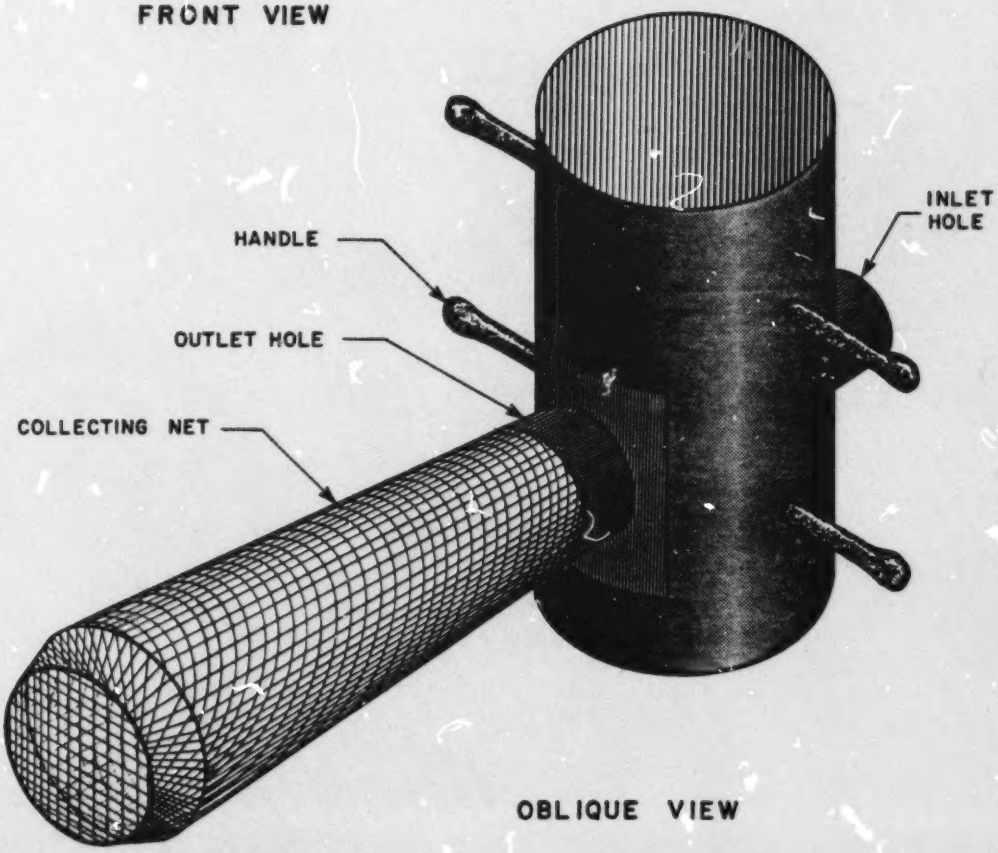
Place the cylinder over the sample area and twist, while exerting downward pressure, forcing the cylinder bottom into the substrate as far as possible. The outlet net should extend downstream.

Remove all large rocks (those with diameters exceeding 10 cm) and pieces of debris (branches) from the inside of the cylinder. The surfaces of rocks should be brushed inside the cylinder to remove attached organisms. No organisms must escape out of the top of the cylinder.

FIG. 1 NEIL CYLINDER BENTHIC SAMPLER



FRONT VIEW



OBLIQUE VIEW

Using the shovel, vigorously stir the substrate for approximately two minutes. This process will loosen the detritus and organisms, allowing them to be swept by the current into the outlet net. Keep pressure on the cylinder to prevent any invertebrates from escaping through the bottom should a strong current lift the cylinder from the substrate.

Removal and Cleaning of the Net:

To remove the net pull it from the cylinder and turn it inside-out into a plastic bucket approximately 1/3-1/2 full of river water or remove the bottle from the net and transfer contents to the sample bottles. Swish the net around to dislodge as many organisms as possible. Using forceps, gently remove any organisms still attached to the cylinder netting and transfer them directly into vials.

Collecting Techniques:

Wet the netting attached to the funnel with river water. Using the plastic beaker, thoroughly swirl around the water and organisms in the bucket. Transfer a beaker full of water and organisms from the bucket to the top of the funnel. Slowly pour the contents of the beaker over the netting of the funnel. Avoid too much material on funnel at any one time. The water and some detritus will pass through the netting and out the bottom of the funnel. The invertebrates to be collected will remain on the netting.

Using forceps, gently transfer all the organisms into vials. Once all organisms have been removed from the funnel net, shake off excess sand debris. Repeat the procedure with another beakerful of water from the bucket. Be sure to thoroughly swirl the water in the bucket before removing each beakerful of water. Swirling keeps the organisms suspended in the water and, assures that some invertebrates will be present in each beakerful. Without swirling, the invertebrates will settle to the bottom. Transfer water and remove organisms from the funnel until no water is left in the bucket. Some sand and organisms will remain in the bottom. Add a small amount of clean water to the bucket, swirl the contents and slowly pour it into the funnel. Gently remove any remaining organisms and place them into vials. It is not necessary to pick through sand since virtually no organisms will be found in sand. Label the vials with the name of the site, location number and date.

The above procedure may be repeated for a minimum of five samples from each station. Each successive sample should be taken approximately 5 metres upstream of the previous sample.

Additional Studies

In addition to being subjected to great amounts of domestic sewage, wastes from industry and mining, urban and rural runoff of pesticides and fertilizers, and other pollutants too numerous to

mention, rivers and streams have also been channeled and diverted, had their flow decreased and increased artificially through the use of dams and otherwise altered from their natural state. One might predict that this would have cumulative effects on the aquatic biota. It is therefore useful to know more about the physical and chemical nature of your sampling area.

While waiting to use the sampling apparatus or after having completed the above procedure, collect field data on the following physical/chemical/biological features of the stream using a commercial water testing kit and other available equipment.

1. depth of water
2. size of stones
3. type of bottom substrate (rocks, silt, sand)
4. productivity (amount of vegetation on bottom: subjective analysis)
5. pH
6. temperature
7. total phosphorous (particulate and dissolved)
8. soluble reactive phosphate
9. dissolved oxygen (D.O.)
10. nitrogen
11. major ions
12. dissolved silica

Your teacher may assign other physical or chemical tests to be carried out.

2. LABORATORY:

A. Materials:

vials containing samples collected
identification keys
dissecting microscope or hand lens
lamps
light microscope
slides
coverslips
distilled water
lens cleaning paper
petri dish
forceps
dissecting needle
data sheets
pencil
vials (containing 70% ethanol)
labels

B. Methods:

Large numbers of many different kinds of organisms are usually collected using the Neil cylinder. To one who is inexperienced at

identifying aquatic invertebrates many of the organisms appear very similar. To begin with then, place the contents of one or two vials into a petri dish or sorting pan. Add a small amount of water. Briefly examine the structural characteristics of the organisms using only your eyes or with a hand lens. Group organisms that resemble one another together in one section of the pan or petri dish. You may end up with several groups of organisms.

Examine the individual organisms in one group using a hand lens or a dissecting scope. Using the taxonomic key: A Guide to the Identification of Fresh-water Invertebrates from Alberta Rivers, identify each organism to the lowest taxonomic level possible. Record the taxa on the data sheet provided. Refer to the sample data sheet on page 8. Place all the organisms in the same taxa into one vial and label it with its name, station number and name, sample number, collection date and your name. Continue identification of the individuals in each group, adding each new taxon to the data sheet and tabulating the numbers of each. Place identical organisms into the same labelled vial. Begin a new vial for each new invertebrate identified. Continue until all specimens collected have been identified and added to the data sheet.

Terresterial invertebrates are not native to the aquatic habitat and should be disposed of (i.e. ants, bees, flies).

BIOLOGICAL MONITORING OF WATER QUALITY

DATA SHEET

RIVER North Saskatchewan River

STATION DESCRIPTION Groat Bridge - Left Bank SAMPLE NO. 1 of 5 SAMPLE DATE 23-04-80

STATION NUMBER 01

COMMENTS: Neil Cylinder; collected by Hampel and Moore; water temp 3°C; depth 36 cm; rocks (0.5 - 15 cm dia)

TAXA NAME	NUMBERS	TAXA NAME	NUMBERS
Nematomorpha	1		
Oligochaeta	5		
Plecoptera	6		
Ephemeroptera	2		
Baetis	15		
Trichoptera	3		
Chironomidae	3		
Corixidae	16		

LIST OF GENERA FOUND IN ALBERTA RIVERS

EPHEMEROPTERA	PLECOPTERA	TRICHOPTERA	DIPTERA
Leptophlebia	Pteronarcys	*Hydropsyche	Blepharaceridae
Paraleptophlebia	Pteronarcella	*Cheumatopsyche	*Tipulidae
Habrophleboides	Taeniopteryx	*Arctopsyche	Tipula
Choroterpes	Brachyptera	Hydroptila	Antocha
Ephoron	Capnia	Agraylea	Pedicia
Ephemera	Leuctra	Ochrotrichia	Limonia
Hexagenia	Nemoura	Psychomyia	Hexatoma
Tricorythodes	Acroneuria	*Rhyacophila	Limnophilia
Caenis	Claassenia	*Glossosoma	Dicranota
*Ephemerella	Acynopteryx	Agapetus	Tanyderidae
Pseudiron	*Isogenus	Molanna	Psychodidae
Epeorus	*Isoperla	Oecetis	Culicidae
*Rhithrogena	*Alloperla	Athripsodes	Simuliidae
Stenonema		Leptocella	Chironomidae
Cinygmula		Beraea	
Cinygma		Helicopsyche	
*Heptagenia		*Brachycentrus	Ceratopogonidae
Ameletus		Micrasema	Tabanidae
Isonychia		Lepidostoma	Rhagionidae
*Baetis		Limnephilus	Empididae
Pseudocloeon			Dolichopodidae
Centroptilum			
Baetisca			

* - Denotes the more common species

LIST OF GENERA FOUND IN ALBERTA RIVERS (cont)

COLEOPTERA
(adults & larvae)

- Curculionidae
- Gyrinidae
- Haliplidae
- Chrysomelidae
- Dryopidae
- Elmidae
- Dytiscidae
- Amphizoidae

HEMIPTERA

- Mesoveliidae
- Corixidae
- Notonectidae

ODONATA

- Agrionidae
- Libellulidae
- Gomphidae
- Aeshni[illegible]

NEUROPTERA

- Sialis

LEPIDOPTERA

- Elophila

GASTROPODA

- Physidae
- Lymnaeidae
- Planorbidae
- Ancylidae

PELYCYPODA

- Unionidae
- Sphaeriidae

NEMATOMORPHA

NEMATODA

TURBELLARIA

- [illegible]esia
- [illegible]ycelis

HIRUDINEA

- Glossiphonia
- Helobdella
- Placobdella
- Erpobdella
- Nephelopsis

OLIGOCHAETA

- Naididae
- *Tubificidae
- Lumbriculidae

HYDRACARINA

AMPHIPODA

- Hyallela
- Pontoporeia
- Gammarus

* - Denotes the more common species

DATA ANALYSIS

At this point you have collected a considerable amount of information in the field (physical, chemical and biological) and have obtained background information from other sources. Where do you go from here?

The purpose of this project is to identify changes in the river or stream and, if possible, relate this to any source of pollutants. The following suggested approach may be of some assistance:

Compare your chemical and physical results to identify differences between sites.

Analyze the biological data using these techniques:

1. Examine the percent distribution of different major groups (i.e. emphemeroptera, plecoptera and trichoptera) usually associated with clean water versus chironomidae and oligochaeta usually found in large numbers in dirty water. Are there differences in the relative number of these groups at the two sites? A change toward the latter may indicate a sewage discharge.

2. Is there a general reduction in numbers at one site or amongst a specific group? This may indicate a toxic effect from some pollutant.

   Other factors besides pollution can cause low diversity and you should use the above techniques and those in the suggested further investigations in conjunction with your physical and chemical data when preparing your report.

Optional Activity

One of the most commonly used methods of analysis is to calculate a diversity index, which is a measure of the number of species present and the number of individuals in each species. Healthy waters in Alberta usually have a high diversity 2.500 or more, mildly polluted 1.500 - 2.500 and heavily polluted less than 1.000. Calculation of diversity indices allows comparison of different sites with different species assemblage at different times and is widely used by pollution biologists. (Use the calculation sheet on the following page for this exercise.)

CALCULATION OF DIVERSITY INDEX

$\bar{H} = -\Sigma_{i=1}^{S} (P_i) (\log_2 P_i)$

Taxon	No. in each Taxon	P_i	Calculation: $(P_i) \times (\log_2 P_i)$ — Enter the following information into a calculator: P_i log ÷ 0.301 =
Total No. of organisms			
Total No. of Taxa			

Questions for Further Investigation

A stream ecosystem is composed of numerous physical, chemical, and biological processes interacting together. Many streams are very chemically and physically dynamic and bilogically rich, tending to reflect the conditions of drainage area. The questions raised in this enrichment section are meant to assist you in recognizing the role of the stream or river you are sampling within a larger ecosystem.

1. What is the problem you are studying? What are the variables involved?

2. Why did you select the area you did to sample? Why did you not pick the other side of the river? Would there be differences in what organisms would be found?

3. When numerous tributaries are entering a main stream it is important to know the watershed (boundaries of the drainage network or basin) in order to understand the relationships of nutrient cycles and chemical/physical/geological factors influencing the river. How would you determine those boundaries? For example, what are some of the advantages and disadvantages of constructing a drainage network from a topographic map?

4. What effect does current have on determining what organisms are found in the channel? Note that riffles are areas of erosion and scouring due to the faster current whereas pools are areas of slower currents and therefore areas of deposition. How could you measure the rate of flow of the current?

5. The stream flow or discharge increases to a peak following a rainstorm or snowmelt period, then decreases. What effect would this have on the organisms found in your sampling area?

6. Why did you not pick through the sand in your sampling?

7. Why did you stir the substrate to sample your area? How effective is this? What problems may arise in your sampling?

8. How can invertebrates be used as a measure of pollution? Why didn't we use fish or other large, mobile freshwater animals?

9. Since many aquatic macroinvertebrates have restricted distributions in the first and second larval instars, how would this affect your sampling?

10. Immature stages of the order Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), Neuroptera, and certain Diptera are the dominant taxa in headwater streams. What differences did you find between this and your sampling area? Why might this occur?

11. Many aquatic organisms have certain traits that enable them to maintain their position and survive in rapidly flowing waters, for

example, some mayflies have become dorosoventrally flattened. These mayflies are found close to the substrate where the water velocity is nearly zero even though they inhabit very rapid water. As you investigate the stream ecosystem note the variety of microhabitats available to stream organisms and adaptations made by the organisms. What relationships are apparent?

12. What relationships exist between the patchy distribution and abundance of organisms in a stream and the availability of microhabitats?

13. What types of invertebrates predominate in riffles? In pools? Which is richer in stream invertebrates, a pool or riffle?

14. What differences might you expect between invertebrates you would find much further upstream and those you would find downstream from your sampling position? Why would these differences occur?

15. Were you able to detect zooplankton and phytoplankton in your water samples? What relationships may be established accounting for the abundance or lack of each of the organisms?

16. Why would you dispose of terrestrial invertebrates not native to the aquatic habitat of your sampling area?

17. What effect would solar radiation have on your sampling area? What changes might you expect at night?

18. Construct a food web for your stream ecosystem and note the energy relationships involved.

19. What effect, if any, would temperature have on the concentrations of dissolved oxygen available in the river? What consequences would this have on the organisms found in your sampling area? What effect would a change in the heat content of a stream or river have on the types or organisms found? Remember that temperature is a measurement of the intensity, not the quantity of heat. What would be the effect of discharging heated water into your sampling area?

20. Are there relationships between concentrations of phosphorus and amounts of dissolved oxygen?

21. What does the concentration of soluble phosphate mean in terms of utilization of photosynthetic organisms?

22. What sources of nitrogen are available for your river ecosystem? How is nitrogen lost from the ecosystem?

23. The amount of dissolved salts in water is of major importance to maintenance of life. In addition to bicarbonates, carbonates, hydroxides and other minerals present in your water samples there may be moderate amounts of silica and chlorides, sulfates, and nitrates of calcium, magnesium, sodium, and potassium. How could

you tell if the geochemical relationships involving these in your river have been altered?

24. The quantity and kinds of dissolved compounds present collectively shift the pH to the alkaline side of neutrality resulting in alkalinity of fresh waters. Is this observable in your sample area? What might account for a shift toward the acid side of neutrality? How would this affect the organisms you have found in your sampling area?

25. Particulate organic matter of a given size may be a major food source whereas very little dissolved organic matter is utilized by aquatic animals directly. Does there seem to be relationships between organic matter identifiably present and the organisms you have found?

26. Photosynthetic populations in aquatic ecosystems can have photosynthetic rates, rates of nutrient utilization, and grazing rates affected by changes in species composition. What relationships are identifiable in the photosynthetic communities within your sampling area?

27. What would be the major ecological effects of sewage discharge on the stream ecosystem in your sample area? Is there any evidence of this? What conclusions might you reach using supporting evidence?

28. What components of your river or stream ecosystem are more sensitive to addition of pollutants? Why? How would you define a pollutant in terms of your sampling area?

29. What would be the advantages of discharging sewage effluents onto land rather than into streams? Would there be disadvantages?

30. What resources have you used to help you with your study? Are there other resources which may help?

STUDENT LABORATORY PROJECT WRITE-UP

The collected data should now be organized into proper format, analyzed and interpreted in the form of a written paper. To assist you in writing your project both the biological and chemical data can be made available to you by Alberta Environment through your instructor.The numbers of questions on pages 13-15 are given in the left-hand margin. These may be used to guide your thoughts as you write each section of your report. An approximate length for each section is given in brackets.

The paper should be organized as follows:

1. INTRODUCTION (three pages)

The introduction and the paper in its entirety must answer the following questions:

Who: Names of the individual(s) involved in the research study.

What: Which group of organisms was studied
What were the reasons for choosing this group
What chemical tests were performed
What physical tests were performed

Where: Describe the sites where sampling was done. Include a description of exact location and a general description of the area (width, surrounding vegetation, presence of slime growths, algae, aquatic plants). You may include photographs, diagram or map of river with sampling locations indicated.

When: Date of sampling, dates report was written and when report was completed.

Why: State the purpose of the project (objectives), specifically, why are living organisms collected and used to determine water quality? State possible questions which will be answered by the report.

Background Information: How is the water used by industry and municipalities; what are the discharges?

II METHODS (two pages)

This section should include a description of the field sampling methods, (both benthic, physical and chemical) including equipment used. In addition, there should also be a description of the follow-up laboratory procedures for the benthos listing equipment used. Methods of chemical analysis may be replaced by reference to the procedures followed from a particular source. Any deviations from the procedure must be stated.

III RESULTS (five pages)

If two sites were examined, the report should include two data tables for the invertebrates collected at each site and two data tables for the chemical/physical characteristics at each site. Each data table must be properly completed and identified as to site and location.

Calculate species diversity index (optional) or other calculations required by your teacher.

A combined class data table for the two sites must also be included.

Design a table which gives (in a very concise form) the physical/chemical data and the diversity index (optional) from both sampling sites obtained by each group in the class.

IV. DISCUSSION (five pages)

The discussion should cover several areas. They are outlined below:

1. Interpretation of the data:

   - What is the significance of the results?
   - Compare and explain the differences in the data from the two sites.
   - Use the background information to help explain the results and to draw inferences.

2. Validity of the Results: How valid is the data obtained considering the limitations of the:

   - experimental design
   - equipment used
   - procedures in the field
   - procedures in the lab
   - time
   - number of repetitions

3. Compare your results to data obtained by other groups or other research.

4. Application of the data with reference to:

   - effect on the environment of discharge from industry and municipalities
   - use of the information obtained by the general public
   - suggestions as to possible action for controlling or eliminating the problem

V. CONCLUSION (one page)

Give your own opinion of the significance of the data obtained using reference to the data to support your opinion.

VI. BIBLIOGRAPHY or Literature Cited (two pages)

Give your own opinion of the significance of the data obtained using reference to the data to support your opinion.

List references alphabetically using the author's last name. If the reference is a research paper taken from a periodical or magazine, the following information should be given:

Author(s), Year. "Title of article", in Title at periodical or magazine, Volume #: pages.

For example:

Jones, J. G. 1972. "Studies on fresh-water micro-organisms: phosphates activity in lakes of differing degrees of eutrophication", in Journal of Ecology, 60: 777-791.

If there is more than one author, list the first author using his last name first, followed by his first name or initials. Give the other authors starting with their first names before their last names.

For example:

Kellogg, W. W., R. D. Cadle, E. R. Allen, A. L. Lazrus, and E. A. Martell, 1972. "The sulfur cycle, " in Science, 175: 587-596.

If the reference is a book, the following information should be given as outlined:

Author, Year. Title, Publisher, Place of publication.

For example:

Hynes, H. B. N., 1960 The biology of polluted water, Liverpool University Press, Liverpool.

If the book has numerous authors, often the editor's name is used instead and is identified as the editor.

For example:

Edmondson, W. T., (ed), 1959. Fresh-water biology, 2nd ed., John Wiley and Sons Inc., New York.

Occasionally references are used in which the author is not given. Such references should be listed separately at the end of the bibliography. They should be arranged in alphabetical order according to the title. The information should be arranged as follows:

Title, Year. Publisher, Place of publication.

For example:

Simplified laboratory procedures for wastewater examination, 1969. WPCF Publications #18, Water Pollution Control Federation, 3900 Wisconsin Ave., Washington, D. C., 30016.

INFORMATION ON WRITING A SCIENTIFIC PAPER

1. The paper should be written in the past tense.
   For example: A Neil cylinder was used to collect benthic invertebrates.

2. The paper should be written in the third person.
   For example: It was found that numerous stonefly larvae were present.
   Incorrect: We found that .....
   I found that .....

3. No contractions should be used such as:
   don't instead of do not,
   etc, instead of etcetera,
   e.g. instead of for example.

4. It is not necessary to underline terms for emphasis.

5. No headings should be used other than those outlined in the write-up:

   Introduction
   Methods
   Results
   Discussion
   Conclusion
   Bibliography

6. Avoid rhetorical questions, that is, those asked not for information but for effect.
   For example: Is anyone concerned about the quality of water in the North Saskatchewan river?

7. Avoid "motherhood and apple pie" statements
   For example: Clean water is the right of every human being.

The Use of References in a Research Paper

Two methods of citing references are outlined below: footnoting and literature cited. Only one method should be used for the entire paper.

1. Footnotes: In this method, any information such as statistics or statements made by another author are quoted word for word. The information is placed in quotation marks and a raised number is given indicating which footnote to see at the bottom of the page. The numbers are assigned in numerical order beginning with the number 1.

For example:

"The amount of CO2 added to the atmosphere by the oxidation of these geologic reserves was calculated to be 10 billion metric tons for 1960 (1)"

At the bottom of the page give the quotation number followed by the title of the reference and the page number from which the quotation was obtained.

For Example:

1. Textbook of limnology, page 183.

   If the quotation is three lines or less then it may be included in the body of the paragraph. If the quotation is over three lines long then it is necessary to indent and single space.

2. Literature Cited: In this method any statistical information or research information obtained from another author must be cited. Immediately following the statement containing the acquired information, place, in brackets, the last name of the author and the year in which the information was published.

   For example:
   The most distressing case is that of the ruination of the complex biota of Lake Atitlan, Guatemala (Geyer, 1973).

   The name of the author may be used directly in the statement and the year following in brackets.

   For example:
   Redfield (1958) reviewed data showing that the relative composition of phosphorus and nitrogen in marine plankters is nearly identical to the ratio in seawater.

All references stated must also be given in an expanded form at the end of the paper. Follow the same format as outlined in the "Bibliography" section.

Title Page

On the following page is the correct format for a title page. The title page must be on 8 1/2 x 11 inch white unlined paper. All information should be centered on the page. The amount of space between each successive line is indicated.

4 cm

TITLE

1 cm

by: C.P. Harris

6 cm

A paper presented to Ross Sheppard
Composite High School partial
fulfillment of the requirements for
Biology 30

10 cm

Edmonton, Canada, 1981

2.5 cm

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